

Chapter 6

Introduction to Celestial Navigation

Introduction

In modern day navigation, we have grown dependent on advanced satellite navigation systems (GPS) to accommodate our day-to-day navigation needs. However, celestial navigation is still very much a part of a day's work in navigation. You may ask yourself why we still use celestial navigation with all the high tech equipment available to find the ship's position. The answer is simple. In wartime, there is always a possibility that satellite tracking stations and satellites themselves may be knocked out. As a Quartermaster, you must make every attempt to hone your celestial skills.

In this chapter, you will learn the basics of celestial navigation. The information contained in this chapter will help you to understand the more complex topics contained in chapter 9.

Objectives

The material in this chapter will enable the student to:

- Describe the celestial sphere.
- Describe the Celestial Coordinate System.
- Use *The Nautical Almanac*.
- Determine the LMT of sunrise, sunset, and twilight.
- Determine LMT of moonrise and moonset.
- Determine LHA of Aries, selected stars, and star time using *The Nautical Almanac*, Pub 249, and *The Rude Starfinder*.

Topic	Page
Earth and the Celestial Sphere	6-2
Understanding the Celestial Coordinate System	6-3
Using <i>The Nautical Almanac</i>	6-5
How to Determine the Time of Sunrise, Sunset, and Twilight	6-6
How to Determine the Time of Moonrise and Moonset	6-8
How to Determine Selected Stars Using Pub 249	6-9
How to Determine Selected Stars Using <i>The Rude Starfinder</i>	6-12

Earth and the Celestial Sphere

Introduction

As you know, Earth is actually an oblate spheroid, just as with chart projections, we consider Earth a perfect sphere for celestial observations.

Celestial Sphere

Simply stated, the celestial sphere is an imaginary sphere that stretches out to the ends of the universe. At the very center of the celestial sphere is Earth. As you know, Earth rotates on its axis from west to east. Because of this rotation, celestial bodies appear to be in motion, rising in the east then crossing over the observer's meridian and going on to set in the west.

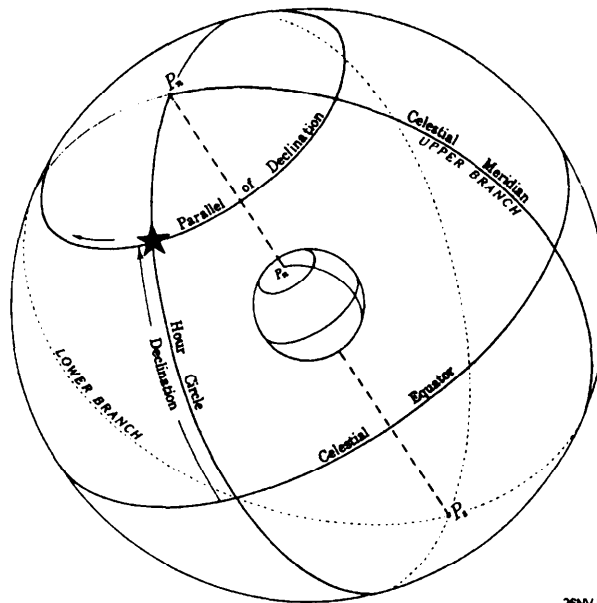


Figure 6-1. Celestial sphere revolving about Earth.

Celestial Poles, Equator, and Meridians

The celestial poles are located by extending Earth's north and south poles (fig. 6-1). The celestial equator (also known as the *equinoctial*) is formed by extending Earth's equator out onto the celestial sphere. Meridians are formed by hour circles that are similar to great circles. The celestial meridian is formed by extending the Greenwich meridian out onto the celestial sphere.

Understanding the Celestial Coordinate System

Components

The Celestial Coordinate System is very similar to the Terrestrial Coordinate System. Use the following table and figure 6-2 to become familiar with the components of the Celestial Coordinate System.

Term	Description
Celestial Equator	The celestial equator is the point of reference for measuring declination .
Declination	Declination can be thought of as the celestial equivalent to latitude. Declination is expressed in the same manner as latitude, measured north or south from 0° through 90°.
First Point of Aries	The first point of Aries can be thought of as the reference point for measuring angles for stars and planets (celestial bodies).
Hour Circles	The great circles that encircle the celestial sphere in the same manner that meridians of longitude encircle Earth. The major difference is that hour circles are measured from 0° westward through 360°. As you know, longitude on the other hand is measured east or west from 0° through 180°. Hour circles move with each celestial body. The 0° meridian is called the <i>Greenwich meridian</i> .
Greenwich Hour Angle (GHA)	GHA is the angular measurement of a celestial body measured westward 0° through 360° from the Greenwich meridian.
Local Hour Angle (LHA)	LHA of a celestial body is measured westward from 0° through 360° from the observers meridian to the hour circle of the celestial body.
Sidereal Hour Angle (SHA)	The SHA is the hour circle of a star or planet measured westward from the first point of Aries from 0° through 360°.

Understanding the Celestial Coordinate System, Continued

To help you visualize the celestial coordinate system, always imagine Earth at the center of the celestial sphere. These facts and figure 6-2 should help you visualize the celestial coordinate system.

Facts

- The first point of Aries is the starting point for all celestial observations.
- Celestial bodies are in constant motion (that's why it was stressed in chapter 5 that the *exact time of a celestial observation must be recorded*).
- The use of GHA associates all hour circles of any celestial body with the Greenwich meridian on Earth. This allows all celestial bodies to be positioned at any moment on the celestial sphere.
- The GHA of Aries will align Aries with the Greenwich meridian.

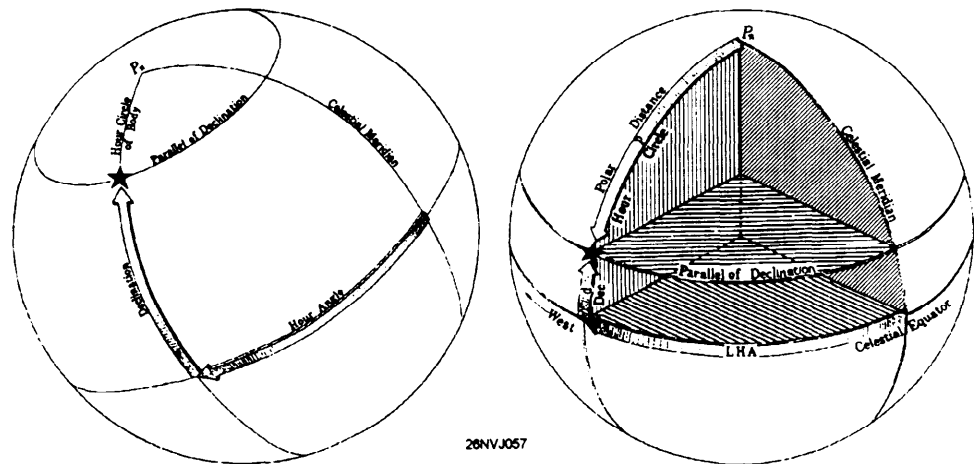


Figure 6-2. The celestial coordinate system.

Using *The Nautical Almanac*

Format

The Nautical Almanac is laid out in what are called daily pages. Each daily page contains astronomical data for 3 days. The left-hand pages contain values for GHA and Dec. (declination) for Aries, Venus, Mars, Jupiter, Saturn, and the 57 navigational stars. The right-hand pages contain values for GHA, Dec., sunrise, sunset, moonrise, moonset, the time of meridian passage for the Sun, and equation of time.

The inside cover contains altitude correction tables for the Sun, stars, and planets, and values for the dip of the horizon correction. After the daily pages are instructions for sight reduction, arc to time conversion table, and interpolation tables, and on the inside back cover are altitude correction tables for the Moon.

Figure 6-3 contains excerpts from *The Nautical Almanac*. As we work through practical examples in celestial navigation, you will learn how to use the information in *The Nautical Almanac*.

108		1991 MAY 28, 29, 30 (TUES., WED., THURS.)												
UT (GMT)	d h m	ARIES		VENUS -4.2		MARS +1.6		JUPITER -1.9		SATURN +0.5		STARS		
		G.H.A.	Dec.	G.H.A.	Dec.	G.H.A.	Dec.	G.H.A.	Dec.	G.H.A.	Dec.	Name	S.H.A.	Dec.
28 00	245 02.3	132 15.9	N24 27.8	121 34.4	N21 25.1	114 02.0	N18 53.2	295 48.1	S18 56.8	315 31.2	S40 28.2	Acorner	315 31.2	S40 28.2
01	260 04.8	147 15.5	27.3	136 37.3	24.7	129 04.1	53.1	310 50.6	56.8	335 39.3	S57 16.5	Acheron	335 39.3	S57 16.5
02	275 07.3	162 15.1	26.9	151 38.2	24.4	144 06.1	53.0	325 53.1	56.8	173 27.7	S63 03.5	Acrus	173 27.7	S63 03.5
03	290 09.7	177 14.7	26.5	166 39.2	24.0	159 08.2	52.9	340 55.6	56.8	235 25.8	S28 57.7	Adhara	235 25.8	S28 57.7
04	305 12.2	192 14.3	26.0	181 40.1	23.7	174 10.3	52.8	355 58.1	56.8	291 08.7	N16 29.6	Aldebaran	291 08.7	N16 29.6
05	320 14.7	207 13.9	25.6	196 41.0	23.4	189 12.4	52.7	11 00.6	56.8					
06	335 17.1	222 13.5	N24 25.2	211 42.0	N21 23.0	204 14.5	N18 52.6	26 03.1	S18 56.9	166 34.6	N56 00.5	Albath	166 34.6	N56 00.5
07	350 19.6	237 13.1	24.7	226 42.9	22.7	219 16.5	52.5	41 05.7	56.9	153 11.4	N49 21.4	Alhaid	153 11.4	N49 21.4
T 08	5 22.1	252 12.8	24.3	241 43.9	22.3	234 18.6	52.4	56 08.2	56.9	28 04.2	S46 59.9	Al Ma'ir	28 04.2	S46 59.9
U 09	20 24.5	267 12.4	23.9	256 44.8	22.0	249 20.7	52.3	71 10.7	56.9	276 03.4	S 1 12.4	Alnham	276 03.4	S 1 12.4
E 10	35 27.0	282 12.0	23.4	271 45.7	21.7	264 22.8	52.2	86 13.2	56.9	218 12.4	S 8 37.4	Alphard	218 12.4	S 8 37.4
S 11	50 29.5	297 11.6	23.0	286 46.7	21.3	279 24.9	52.1	101 15.7	56.9					
D 12	65 31.9	312 11.2	N24 22.6	301 47.6	N21 21.0	294 26.9	N18 52.0	116 18.2	S18 57.0	126 24.6	N26 44.5	Alphecca	126 24.6	N26 44.5
A 13	80 34.4	327 10.8	22.1	316 48.5	20.6	309 29.0	51.9	131 20.7	57.0	358 00.8	N29 02.5	Alpharatz	358 00.8	N29 02.5
Y 14	95 36.8	342 10.5	21.7	331 49.5	20.3	324 31.1	51.8	146 23.2	57.0	146 23.2	S7.0	Alhai	146 23.2	S7.0
15	110 39.3	357 10.1	21.2	346 50.4	19.9	339 33.2	51.7	161 25.7	57.0	353 32.0	S42 20.9	Ankaa	353 32.0	S42 20.9
16	125 41.8	12 09.7	20.8	1 51.3	19.6	354 35.2	51.6	176 28.2	57.0	176 28.2	S26 24.9	Antares	176 28.2	S26 24.9
17	140 44.2	27 09.3	20.4	16 52.3	19.2	37 37.3	51.5	191 30.7	57.0					
18	155 46.7	42 09.0	N24 19.9	31 53.2	N21 18.9	24 39.4	N18 51.4	206 33.3	S18 57.0	146 10.4	N19 13.5	Arcturus	146 10.4	N19 13.5
19	170 49.2	57 08.6	19.5	46 54.1	18.6	39 41.5	51.3	221 35.8	57.1	108 02.4	S69 00.9	Atia	108 02.4	S69 00.9
20	185 51.6	72 08.2	19.0	61 55.1	18.2	54 43.5	51.2	236 38.3	57.1	236 38.3	S59 29.2	Avior	236 38.3	S59 29.2
21	200 54.1	87 07.8	18.6	76 56.0	17.9	69 45.6	51.1	251 40.8	57.1	278 50.0	N 6 20.6	Bellatrix	278 50.0	N 6 20.6
22	215 56.6	102 07.5	18.1	91 57.0	17.5	84 47.7	51.0	266 43.3	57.1	271 19.5	N 7 24.4	Betelgeuse	271 19.5	N 7 24.4
23	230 59.0	117 07.1	17.7	106 57.9	17.2	99 49.8	50.9	281 45.8	57.1					
29 00	246 01.5	132 06.7	N24 17.2	121 58.8	N21 16.8	114 51.9	N18 50.8	296 48.3	S18 57.2	264 04.0	S52 41.6	Canopus	264 04.0	S52 41.6
01	261 04.0	147 06.4	16.8	136 59.8	16.5	129 53.9	50.7	311 50.8	57.2	280 59.4	N45 59.5	Capella	280 59.4	N45 59.5
										49 42.6	N45 14.7	Deneb	49 42.6	N45 14.7
										182 50.3	N14 37.1	Denebola	182 50.3	N14 37.1
										349 12.6	S18 01.9	Diphda	349 12.6	S18 01.9

109		1991 MAY 28, 29, 30 (TUES., WED., THURS.)											
UT (GMT)	d h m	SUN		MOON		Lat.	Twilight		Sunrise	Moonrise			
		G.H.A.	Dec.	G.H.A.	Dec.		Naut.	Civil		28	29	30	31
28 00	180 43.4	N21 20.6	7 13.9	10.8	S24 06.9	4.6	54.5	N 72	01 27	01 27	01 27	01 27	01 27
01	195 43.3	21.0	21 43.7	10.8	24 11.5	4.5	54.5	68	01 27	01 27	01 27	01 27	01 27
02	210 43.2	21.4	36 13.5	10.7	24 16.0	4.3	54.5	66	01 27	01 27	01 27	01 27	01 27
03	225 43.1	21.8	50 43.2	10.8	24 20.3	4.3	54.4	64	01 27	01 27	01 27	01 27	01 27
04	240 43.1	22.3	65 13.0	10.7	24 24.6	4.1	54.4	62	01 27	01 27	01 27	01 27	01 27
05	255 43.0	22.7	79 42.7	10.6	24 28.7	4.0	54.4	60	01 27	01 27	01 27	01 27	01 27
06	270 42.9	N21 23.1	94 12.3	10.7	S24 32.7	3.9	54.4	N 58	01 27	01 27	01 27	01 27	01 27
07	285 42.9	23.5	108 42.0	10.6	24 36.6	3.7	54.4	56	01 27	01 27	01 27	01 27	01 27
08	300 42.8	23.9	123 11.6	10.6	24 40.3	3.7	54.4	54	01 27	01 27	01 27	01 27	01 27
09	315 42.7	24.3	137 41.2	10.6	24 44.0	3.5	54.4	52	01 27	01 27	01 27	01 27	01 27
10	330 42.6	24.7	152 10.8	10.6	24 47.5	3.4	54.4	50	01 27	01 27	01 27	01 27	01 27
11	345 42.6	25.1	166 40.4	10.6	24 50.9	3.3	54.4	48	01 27	01 27	01 27	01 27	01 27
12	0 42.5	N21 25.5	181 10.0	10.5	S24 54.2	3.1	54.4	N 40	01 27	01 27	01 27	01 27	01 27
13	15 42.4	25.9	195 39.3	10.5	24 57.3	3.1	54.3	35	01 27	01 27	01 27	01 27	01 27
14	30 42.3	26.3	210 09.0	10.5	25 00.4	2.9	54.3	30	01 27	01 27	01 27	01 27	01 27
15	45 42.3	26.7	224 38.5	10.5	25 03.3	2.8	54.3	20	01 27	01 27	01 27	01 27	01 27
16	60 42.2	27.1	239 08.0	10.5	25 06.1	2.6	54.3	N 10	01 27	01 27	01 27	01 27	01 27
17	75 42.1	27.5	253 37.5	10.5	25 08.7	2.4	54.3	0	01 27	01 27	01 27	01 27	01 27
18	90 42.0	N21 27.9	268 07.0	10.5	S25 11.3	2.4	54.3	S 10	01 27	01 27	01 27	01 27	01 27
19	105 42.0	28.3	282 36.5	10.4	25 13.7	2.3	54.3	20	01 27	01 27	01 27	01 27	01 27
20	120 41.9	28.7	297 05.9	10.4	25 16.0	2.1	54.3	30	01 27	01 27	01 27	01 27	01 27
21	135 41.8	29.1	311 35.3	10.5	25 18.1	2.1	54.3	35	01 27	01 27	01 27	01 27	01 27
22	150 41.7	29.5	326 04.8	10.4	25 20.2	1.9	54.3	40	01 27	01 27	01 27	01 27	01 27
23	165 41.7	29.9	340 34.2	10.4	25 22.1	1.8	54.3	45	01 27	01 27	01 27	01 27	01 27
29 00	180 41.6	N21 30.3	355 03.6	10.4	S25 23.9	1.7	54.2	S 50	01 27	01 27	01 27	01 27	01 27
01	195 41.5	30.7	9 33.0	10.4	25 25.6	1.5	54.2	52	01 27	01 27	01 27	01 27	01 27
02	210 41.4	31.1	24 02.4	10.5	25 27.1	1.5	54.2	54	01 27	01 27	01 27	01 27	01 27
03	225 41.3	31.5	38 31.9	10.4	25 28.6	1.3	54.2	56	01 27	01 27	01 27	01 27	01 27
04	240 41.3	31.9	53 01.3	10.4	25 29.9	1.2	54.2	58	01 27	01 27	01 27	01 27	01 27
05	255 41.2	32.3	67 30.7	10.4	25 31.1	1.0	54.2	S 60	01 27	01 27	01 27	01 27	01 27
06	270 41.1	N21 32.7	82 00.1	10.4	S25 32.1	0.9	54.2						
07	285 41.0	33.1	96 29.5	10.4	25 33.0	0.9	54.2						
08	300 41.0	33.5	110 58.9	10.4	25 33.9	0.8	54.2						
09	315 40.9	33.9	125 28.3	10.4	25 34.5	0.8	54.2						
10	330 40.8	34.3	139 57.7	10.4	25 35.1	0.4	54.2						
11	345 40.7	34.7	154 27.1	10.4	25 35.5	0.3	54.2						
12	0 40.6	N21 35.1	168 56.5	10.5	S25 35.8	0.2	54.2	N 70	01 27	01 27	01 27	01 27	01 27
13	15 40.6	35.5	183 26.0	10.4	25 36.0	0.1	54.2	68	01 27	01 27	01 27	01 27	01 27
14	30 40.5	35.9	197 55.4	10.4	25 36.1	0.1	54.1	66	01 27	01 27	01 27	01 27	01 27
15	45 40.4	36.2	212 24.8	10.5	25 36.0	0.2	54.1	64	01 27	01 27	01 27	01 27	01 27
16	60 40.3	36.6	226 54.3	10.5	25 35.8	0.3	54.1	62	01 27	01 27	01 27	01 27	01 27
17	75 40.2	37.0	241 23.8	10.4	25 35.5	0.4	54.1	60	01 27	01 27	01 27	01 27	01 27
18	90 40.2	N21 37.4	255 53.2	10.5	S25 35.1	0.6	54.1	N 58	01 27	01 27	01 27	01 27	01 27
19	105 40.1	37.8	270 22.7	10.5	25 34.5	0.6	54.1	56	01 27	01 27	01 27	01 27	01 27

110		1991 MAY 28, 29, 30 (TUES., WED., THURS.)											
UT (GMT)	d h m	SUN		MOON		Lat.	Twilight		Sunrise	Moonrise			
		G.H.A.											

How to Determine the Time of Sunrise, Sunset, Moonrise, Moonset, and Twilight

Strip Forms and the Navigation Workbook

OPNAV Navigation Strip Forms have evolved from a need to have a standard method of working celestial problems. The strip forms are located in the back of the Navigation Workbook (OPNAV 3530/l) and they are designed to work with the individual pages of the Navigation Workbook. Every time a celestial observation is taken that fixes the ship's position, you must keep a record of the results in the Navigation Workbook.

How to Determine the Time of Sunrise

We will learn how to determine the time of sunrise by using a practical example. Use the table on the next page and figure 6-4 to work the strip form.

TABLES FOR INTERPOLATING SUNRISE, MOONRISE, ETC.

TABLE I.—FOR LATITUDE

Tabular Interval			Difference between the times for consecutive latitudes											
10"	5"	1"	15"	10"	5"	1"	15"	10"	5"	1"	15"	10"	5"	1"
0 30	0 15	0 06	0 0	0 1	1 1	1 1	1 2	2 2	2 2	0 02	0 02	0 02	0 02	0 02
1 00	0 30	0 13	0 1	1 1	3 3	3 3	3 4	4 5	4 5	0 05	0 05	0 05	0 05	0 05
1 30	0 45	0 18	1 1	1 2	3 4	4 4	4 5	5 6	5 6	0 07	0 07	0 07	0 07	0 07
2 00	1 00	0 34	1 2	3 4	4 5	5 5	6 7	8 9	10 10	0 10	0 10	0 10	0 10	0 10
2 30	1 15	0 30	1 2	4 4	5 6	6 7	8 9	9 9	10 11 12	0 12	0 13	0 13	0 13	0 13
3 00	1 30	0 36	1 3	4 6	6 7	8 8	9 10	11 11	12 13 14	0 15	0 15	0 16	0 16	0 16
3 30	1 45	0 43	2 3	5 7	8 10	11 12	13 14	14 16	17 18	0 18	0 18	0 19	0 19	0 19
4 00	2 00	0 48	2 4	6 8	9 11	13 14	15 16	18 19	20 21	0 22	0 22	0 22	0 22	0 22
4 30	2 15	0 54	3 4	7 9	11 13	15 16	18 19	21 22	23 24	0 25	0 25	0 26	0 26	0 26
5 00	2 30	1 00	3 5	7 10	12 14	16 18	20 22	23 25	26 27	0 28	0 28	0 29	0 29	0 29
5 30	2 45	1 06	3 5	8 11	13 16	18 20	22 24	26 28	29 30	0 30	0 30	0 31	0 31	0 31
6 00	3 00	1 13	4 6	9 12	14 17	20 22	24 26	29 31	32 33	0 33	0 33	0 34	0 34	0 34
6 30	3 15	1 18	4 6	10 13	16 19	22 24	26 28	31 34	35 37	0 36	0 36	0 37	0 37	0 37
7 00	3 30	1 24	4 7	10 14	17 20	23 26	29 31	34 37	39 40	0 40	0 40	0 41	0 41	0 41
7 30	3 45	1 30	4 7	11 15	18 22	25 28	31 34	37 40	43 44	0 43	0 43	0 44	0 44	0 44
8 00	4 00	1 36	4 8	12 16	20 23	27 30	34 37	41 44	0 47	0 48	0 48	0 51	0 51	0 51
8 30	4 15	1 42	4 8	13 17	21 25	29 33	36 40	44 48	0 51	0 53	0 53	0 56	0 56	0 56
9 00	4 30	1 48	4 9	13 18	22 27	31 35	39 43	47 52	0 55	0 58	0 58	0 61	0 61	0 61
9 30	4 45	1 54	5 9	14 19	24 28	33 38	41 47	51 56	1 00	0 04	0 04	0 08	0 08	0 08
10 00	5 00	2 00	5 10	15 20	25 30	35 40	45 50	55 60	1 05	0 10	0 10	0 15	0 15	0 15

Table I is for interpolating the L.M.T. of sunrise, twilight, moonrise, etc., for latitude. It is to be entered, in the appropriate column on the left, with the difference between true latitude and the nearest tabular latitude which is less than the true latitude; and with the argument at the top which is the nearest value of the difference between the times for the tabular latitudes. The value obtained is applied to the time for the tabular latitude. It is to be noted that the interpolation is not linear, so tabular phenomenon for the latitude less than the true

Lat.	Sunset	Twilight		Moonset			
		Civil	Naut.	1	2	3	4
N 72	19 53	21 20	22 20	18 00	18 00	18 00	18 00
N 70	19 40	20 54	22 29	17 50	17 50	17 50	17 50
68	19 30	20 34	22 17	17 40	17 40	17 40	17 40
66	19 21	20 19	21 42	17 30	17 30	17 30	17 30
64	19 14	20 06	21 18	16 22	17 43	18 06	18 10
62	19 08	19 56	21 05	16 50	17 29	17 47	17 50
60	19 02	19 47	20 45	15 07	16 17	16 47	16 50
N 58	18 58	19 39	20 32	14 45	15 53	16 41	17 12
56	18 53	19 33	20 22	14 26	15 34	16 24	16 58
54	18 50	19 27	20 12	14 11	15 18	16 09	16 47
52	18 46	19 21	20 04	13 57	15 04	15 56	16 36
50	18 43	19 17	19 57	13 46	14 51	15 45	16 27
48	18 36	19 07	19 43	13 31	14 37	15 32	16 07
N 40	18 31	18 59	19 37	13 02	14 06	15 03	15 51
38	18 26	18 52	19 22	12 45	13 49	14 47	15 37
36	18 22	18 46	19 15	12 31	13 34	14 33	15 25
34	18 15	18 37	19 03	12 08	13 09	14 09	15 05
N 10	18 09	18 30	18 55	11 47	12 48	13 49	14 47
0	18 03	18 24	18 48	11 28	12 28	13 29	14 30

CONVERSION OF ARC TO TIME

0°-59'	60°-119'	120°-179'	180°-239'	240°-299'	300°-359'	0°-59'	60°-119'	120°-179'	180°-239'	240°-299'	300°-359'
0 0 00	60 1 00	120 2 00	180 3 00	240 4 00	300 5 00	0 0 00	60 1 00	120 2 00	180 3 00	240 4 00	300 5 00
1 0 04	61 1 04	121 2 04	181 3 04	241 4 04	301 5 04	1 0 04	61 1 04	121 2 04	181 3 04	241 4 04	301 5 04
2 0 08	62 1 08	122 2 08	182 3 08	242 4 08	302 5 08	2 0 08	62 1 08	122 2 08	182 3 08	242 4 08	302 5 08
3 0 12	63 1 12	123 2 12	183 3 12	243 4 12	303 5 12	3 0 12	63 1 12	123 2 12	183 3 12	243 4 12	303 5 12
4 0 16	64 1 16	124 2 16	184 3 16	244 4 16	304 5 16	4 0 16	64 1 16	124 2 16	184 3 16	244 4 16	304 5 16
5 0 20	65 1 20	125 2 20	185 3 20	245 4 20	305 5 20	5 0 20	65 1 20	125 2 20	185 3 20	245 4 20	305 5 20
6 0 24	66 1 24	126 2 24	186 3 24	246 4 24	306 5 24	6 0 24	66 1 24	126 2 24	186 3 24	246 4 24	306 5 24
7 0 28	67 1 28	127 2 28	187 3 28	247 4 28	307 5 28	7 0 28	67 1 28	127 2 28	187 3 28	247 4 28	307 5 28
8 0 32	68 1 32	128 2 32	188 3 32	248 4 32	308 5 32	8 0 32	68 1 32	128 2 32	188 3 32	248 4 32	308 5 32
9 0 36	69 1 36	129 2 36	189 3 36	249 4 36	309 5 36	9 0 36	69 1 36	129 2 36	189 3 36	249 4 36	309 5 36

Figure 6-4. Excerpt from *The Nautical Almanac*.

How to Determine the Time of Sunrise, and Sunset..., Continued

Example

In our example, we will assume that at 1500 on 1 Sep 94 our training ship is located at 36° 14.0' N 069° 26' W, on course 090° T at a speed of 10 knots. Problem: find the time of sunset.

OPNAV 3530/38 (4-73) SUNSET/RISE	Step	Action	Completed Strip Form
DR Lat	1.	From <i>the Nautical Almanac</i> note the time of tab sunset for the latitude closest to your current position.	DR Lat 36° 14'N
Tab Interval	2.	Enter the interval between the two latitudes closest to your DR Lat.	Tab Interval 5°
Lat Interval	3.	Enter the time difference between the two latitudes.	Lat Interval 5 min
Lat Diff	4.	Enter the difference between your DR Lat. and the <i>lower tab latitude</i> .	Lat Diff 1°14'
Corr Table I	5.	Go to Correction Table I in the Nautical Alm., follow the instructions at the bottom of the table to determine the time correction.	Corr Table I 1 min
Tab LMT	6.	Enter the time of the tabulated lat., use the tab lat that is lower than your DR Lat.	Tab LMT 1826
Corr LMT	7.	Add the time correction.	Corr LMT 1827
DRλ	8.	Enter the DR Longitude.	DRλ 069° 26'
STD Mer	9.	Enter the value for the time zone that the ship is keeping, in this case +5R express in degrees, 5 x 15 = 75.	STD Mer 075°
dλ(arc)	10.	Find the lat difference between 75° and DRλ 069°26'.	dλ (arc) 5° 34'

How to Determine the Time of Sunrise, and Sunset,..., Continued

dλ(time)	11.	Enter the Arc to Time Conversion table on the left column, finding the time value for 5° (20m) and then enter the right column for 34' (2m 16s) and add the values together for the total time correction.	dλ(time) 22m 16s Round off to closest minute.						
LMT	12.	<div>LMT = Corr LMT + or - dλ(time)</div> <table><tr><th>IF...</th><th>THEN...</th></tr><tr><td>DRλ is less than STD Mer</td><td>Subtract dλ (time) from Corr LMT</td></tr><tr><td>DRλ is greater than STD Mer</td><td>Add dλ (time) to Corr LMT</td></tr></table>	IF...	THEN...	DRλ is less than STD Mer	Subtract dλ (time) from Corr LMT	DRλ is greater than STD Mer	Add dλ (time) to Corr LMT	<div>Corr LMT 1827</div> <div>dλ(time) <u>-22</u></div> <div>LMT = 1802</div>
IF...	THEN...								
DRλ is less than STD Mer	Subtract dλ (time) from Corr LMT								
DRλ is greater than STD Mer	Add dλ (time) to Corr LMT								

How to Determine the Time of Twilight

To find the time of twilight, use the same steps you use to find the time of sunrise or sunset except use the tab values from the twilight column. It is helpful in some operations to know the exact time of twilight.

Finding the Time of Moonrise or Moonset

Use strip form 3530/39 to find the time of moonrise or moonset. The procedure is exactly the same as the one used to find the time of SR or SS except that an additional correction must be made from table II of the *Nautical Almanac*. A correction for the time difference between tab LMT and the preceding or following day must be applied from table II. Simple instructions for this correction can be found at the bottom of table II.

How to Determine Star Time and Selected Stars Using Pub 249 Vol I (Selected Stars)

Example

Determining star time and selected stars for morning or evening observations is simple. The process involves finding the time of sunrise for morning observation or sunset for evening observations. Then you find the LHA of Aries for the time of star time and record the data for the seven stars on a worksheet.

Rule: Add 30 minutes to the time of sunset to determine evening star time, subtract 45 minutes from sunrise to determine morning star time.

Example: The ship is located at 36°14.0' N 069°14' W, the date is 01 Sep 91. The ship is on course 090°T and is keeping +5R time zone.

Discussion

Although there are other methods of determining which navigational stars are available for observations, using Pub 249 is the most widely used method. In step 10, you are directed to record the values for Hc (height computed) and Zn (the azimuth angle, or the true direction to point the sextant towards) on a worksheet. At the time of publication, there is NOT a standard worksheet available for use. A recommended format is supplied on page 11. Use a PC word processor to reproduce this worksheet locally.

Use figure 6-5 on the following page along with the example OPNAV form to find selected stars.

172

1991 SEPTEMBER 1, 2, 3 (SUN., MON., TUE)

UT (GMT)	ARIES	VENUS -4.2	MARS +1.8	JUPITER -1.7	SATURN +0.3
d h	G.H.A.	G.H.A. Dec.	G.H.A. Dec.	G.H.A. Dec.	G.H.A. Dec.
1 00	339 39.7	196 04.6 N 5 41.6	159 32.5 N 0 43.3	189 36.7 N 13 02.9	36 12.0 S 20 25.1
01	354 42.1	211 08.2 42.1	174 33.5 42.6	204 38.7 02.7	51 14.6 25.1
02	9 44.6	226 11.7 42.7	189 34.5 42.0	219 40.6 02.5	66 17.2 25.1
03	24 47.1	241 15.2 43.2	204 35.5 41.3	234 42.5 02.3	81 19.8 25.2
04	39 49.5	256 18.7 43.7	219 36.5 40.7	249 44.5 02.1	96 22.4 25.2
05	54 52.0	271 22.2 44.2	234 37.5 40.0	264 46.4 01.9	111 25.0 25.2
06	69 54.5	286 25.7 N 5 44.7	249 38.5 N 0 39.3	279 48.4 N 13 01.7	126 27.6 S 20 25.3
07	84 56.9	301 29.2 45.2	264 39.5 38.7	294 50.3 01.6	141 30.2 25.3
08	99 59.4	316 32.7 45.7	279 40.5 38.0	309 52.2 01.4	156 32.8 25.3
09	115 01.9	331 36.2 46.1	294 41.5 37.4	324 54.2 01.2	171 35.4 25.4
10	130 04.3	346 39.7 46.8	309 42.5 36.7	339 56.1 01.0	186 38.0 25.4
11	145 06.8	1 43.2 47.3	324 43.5 36.0	354 58.1 00.8	201 40.6 25.4
12	160 09.2	16 46.7 N 5 47.8	339 44.5 N 0 35.4	10 00.0 N 13 00.6	216 43.2 S 20 25.4
13	175 11.7	31 50.2 48.3	354 45.5 34.7	25 01.9 00.5	231 45.8 25.5
14	190 14.2	46 53.7 48.8	9 46.5 34.1	40 03.9 00.3	246 48.4 25.5
15	205 16.6	61 57.1 49.4	24 47.5 33.4	55 05.8 13 00.1	261 51.0 25.5
16	220 19.1	77 00.6 49.9	39 48.5 32.7	70 07.8 12 59.9	276 53.6 25.6
17	235 21.6	92 04.1 50.4	54 49.5 32.1	85 09.7 59.7	291 56.2 25.6
18	250 24.0	107 07.5 N 5 50.9	69 50.5 N 0 31.4	100 11.7 N 12 59.5	306 58.8 S 20 25.6
19	265 26.5	122 11.0 51.4	84 51.5 30.8	115 13.6 59.4	322 01.4 25.7
20	280 29.0	137 14.4 51.9	99 52.5 30.1	130 15.5 59.2	337 03.9 25.7
21	295 31.4	152 17.9 52.5	114 53.5 29.4	145 17.5 59.0	352 06.5 25.7
22	310 33.9	167 21.3 53.0	129 54.4 28.8	160 19.4 58.8	7 09.1 25.7
23	325 36.4	182 24.8 53.5	144 55.4 28.1	175 21.4 58.6	22 11.7 25.8

2 00	340 38.8	197 28.2 N 5 54.0	159 32.5
01	355 41.3	212 31.7 54.5	174 33.5
02	10 43.7	227 35.1 55.0	189 34.5
03	25 46.2	242 38.5 55.6	204 35.5
04	40 48.7	257 42.0 56.1	219 36.5
05	55 51.1	272 45.4 56.6	234 37.5
06	70 53.6	287 48.8 N 5 57.1	249 38.5
07	85 56.1	302 52.2 57.6	264 39.5
08	100 58.5	317 55.6 58.1	279 40.5
09	116 01.0	332 59.0 58.7	294 41.5
M 10	131 03.5	348 02.5 59.2	309 42.5
N 11	146 05.9	3 05.9 59.7	324 43.5

CORRECTIONS

II"

II	SUN	PLANETS	ARIES	MOON	or Corr ^d	or Corr ^d	or Corr ^d	or Corr ^d	or Corr ^d
00	2 45-0	2 45-5	2 37-5	0-0	0-0	6-0	1-2	12-0	2-3
01	2 45-3	2 45-7	2 37-7	0-1	0-0	6-1	1-2	12-1	2-3
02	2 45-5	2 46-0	2 38-0	0-2	0-0	6-2	1-2	12-2	2-3
03	2 45-8	2 46-2	2 38-2	0-3	0-1	6-3	1-2	12-3	2-4
04	2 46-0	2 46-5	2 38-4	0-4	0-1	6-4	1-2	12-4	2-4
05	2 46-3	2 46-7	2 38-7	0-5	0-1	6-5	1-2	12-5	2-4
06	2 46-5	2 47-0	2 38-9	0-6	0-1	6-6	1-3	12-6	2-4
07	2 46-8	2 47-2	2 39-2	0-7	0-1	6-7	1-3	12-7	2-4
08	2 47-0	2 47-5	2 39-4	0-8	0-2	6-8	1-3	12-8	2-5
09	2 47-3	2 47-7	2 39-6	0-9	0-2	6-9	1-3	12-9	2-5
10	2 47-5	2 48-0	2 39-9	1-0	0-2	7-0	1-3	13-0	2-5
11	2 47-8	2 48-2	2 40-1	1-1	0-2	7-1	1-4	13-1	2-5
12	2 48-0	2 48-5	2 40-3	1-2	0-2	7-2	1-4	13-2	2-5
13	2 48-3	2 48-7	2 40-6	1-3	0-2	7-3	1-4	13-3	2-5
14	2 48-5	2 49-0	2 40-8	1-4	0-3	7-4	1-4	13-4	2-6
15	2 48-8	2 49-2	2 41-1	1-5	0-3	7-5	1-4	13-5	2-6
16	2 49-0	2 49-5	2 41-3	1-6	0-3	7-6	1-5	13-6	2-6
17	2 49-3	2 49-7	2 41-5	1-7	0-3	7-7	1-5	13-7	2-6
18	2 49-5	2 50-0	2 41-8	1-8	0-3	7-8	1-5	13-8	2-6
19	2 49-8	2 50-2	2 42-0	1-9	0-4	7-9	1-5	13-9	2-7
20	2 50-0	2 50-5	2 42-3	2-0	0-4	8-0	1-5	14-0	2-7
21	2 50-3	2 50-7	2 42-5	2-1	0-4	8-1	1-6	14-1	2-7
22	2 50-5	2 51-0	2 42-7	2-2	0-4	8-2	1-6	14-2	2-7
23	2 50-8	2 51-2	2 43-0	2-3	0-4	8-3	1-6	14-3	2-7
24	2 51-0	2 51-5	2 43-2	2-4	0-5	8-4	1-6	14-4	2-8
25	2 51-3	2 51-7	2 43-4	2-5	0-5	8-5	1-6	14-5	2-8
26	2 51-5	2 52-0	2 43-7	2-6	0-5	8-6	1-6	14-6	2-8
27	2 51-8	2 52-2	2 43-9	2-7	0-5	8-7	1-7	14-7	2-8
28	2 52-0	2 52-5	2 44-2	2-8	0-5	8-8	1-7	14-8	2-8
29	2 52-3	2 52-7	2 44-4	2-9	0-6	8-9	1-7	14-9	2-9

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Figure 6-5. Excerpts from *The Nautical Almanac*.

How to Determine Star Time and Selected Stars Using Pub 249 Vol I (Selected Stars), Continued

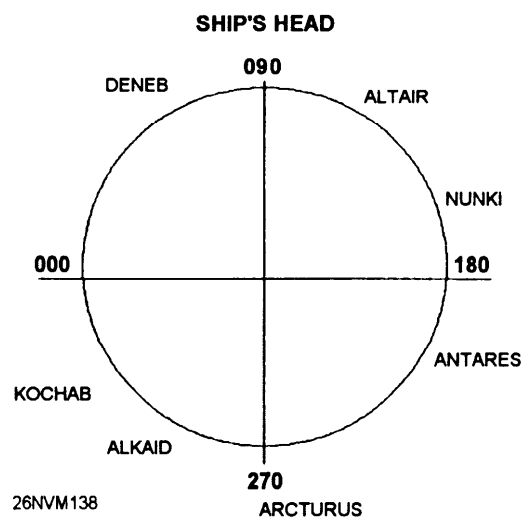
Step	Action	Result
1.	Determine the time of sunset.	1841
2.	Add 30 minutes to the time of sunset (star time). Find and note the DR position for 1911. For our example we will use 36°14.0'N 069°04'W.	1911
3.	Find GMT of star time 1911. Remember to find GMT apply the ZD to LMT.	00h 11m 02 Sep 91
4.	From the left-hand pages of the <i>Nautical Almanac</i> , find the GHA of Aries.	339°39'.7
5.	From the Increments and Corrections pages find the page with 11 ^m and then find the value for Aries for 00 seconds.	2° 45'.5
6.	Find the total GHA of Aries by adding the results from step 4 and 5 together. Remember to carry over 1 whole degree whenever the total minutes are greater than 60. Ex. 85 - 60 = 25 carry 1°.	339°39'.7 + 2° 45'.5 342°25'.2
7.	Find the LHA of Aries by subtracting west longitude, or adding east longitude.	342°25'.2 -069°04'.5 273°21'.2
8.	Round off DR lat. and LHA Aries to the closest °.	DR lat. = 36° N LHA Aries 273°
9.	Enter Pub 249 on the page for 36° N.	
10.	Record the values for Hc and Zn for each star for LHA Aries for 273° on a worksheet.	See example worksheet on next page.

Pub 249 Selected Stars Worksheet

Find the LHA of Aries for star time, use Pub 249 for closest latitude and LHA Aries, record the results.

Name of Star	Hc	Zn	Observed Hc	Observed Zn	GMT of Observation
DENEb	60 30	060			
ALTAIR	54 48	134			
NUNKI	26 53	169			
ANTARES	23 02	205			
ARCTURUS	35 49	269			
ALKAID	41 13	308			
KOCHAB	44 56	343			

Map the Zn of each selected star as it relates to the ship's head just prior to taking sights (celestial observations).



How to Determine Selected Stars using The *Rude Starfinder*

Components

The Rude Starfinder is made up of a plastic star base showing stars of the northern hemisphere on one side, and stars of the southern hemisphere on the other side, and 10 transparent templates. Nine templates printed in blue, with each template covering 10° of latitude, labeled 5° , 15° , 25° , and so on, plus a tenth template printed in red showing meridian angle and declination for use in the plotting of planets. Each latitude template has a family of altitude curves at 5° intervals from the horizon to 80° . From these curves, you can determine the height of a star or planet. A second family of curves, also at 5° intervals, indicate the azimuth (true bearing) of a star or planet. The north-south azimuth line represents the celestial meridian. The star base, templates, and a set of instructions are housed in a leatherette case.

Uses

The starfinder has four purposes: to identify an unknown star, to select several stars for observation, to plot planets for observation, and identify a star's magnitude. For example, when taking sights for evening stars, you shoot a star or planet that is not part of your selected stars list obtained from Pub 249. You can identify the celestial body using the starfinder. This proves to be extremely useful when overcast weather conditions exists.

Using the Starfinder

Follow the steps in the table to create a list of selected stars for observation. Refer to the instructions that are included with the star finder to identify an unknown body.

Step	Action
1.	Find the LHA of Aries for star time, follow steps 1 through 7 on pages 6-12.
2.	Place the template for the latitude closest to the DR latitude on the star base.
3.	Move the pointer to the correct LHA.
4.	Select eight stars that provide 360° of coverage at intervals of about 20° .
5.	Record the height and azimuth of each star. It will be helpful to list stars in the order of increasing azimuth. Example: Vega 019° T, Arcturus 043° T, and so on.